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ABSTRACT

This study of college-bound 11th graders assessed the feasibility and effectiveness of instruction that used a structured cooperative learning technique. The students worked in dyads with scripts that contained two learning situations with two roles: (1) explainer and checker; and (2) solver and checker. Both students then worked on summary questions and homework. Verbal interaction influenced learning and appeared to be a mediator of the effects of student characteristics on achievement. Specifically, the study focused on two questions: (1) Can an effective program using dyadic studying techniques be designed for a high school course in higher mathematics; and (2) When high school students are trained to use a dyadic studying strategy for learning from their text, what is the nature of their verbal interaction and does this interaction change over time? Two groups were compared using the same texts, tests, and teacher. Both questions were answered affirmatively and supported statistically. The study concluded that: (1) students can be expected to respond positively to the experience and to work cooperatively and productively together; and (2) 94% of the time students had on-task interaction. Numerous tables contain specific statistical information. Contains 47 references. (GW)

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STRUCTURED COOPERATIVE LEARNING AND ACHIEVEMENT IN A HIGH SCHOOL MATHEMATICS CLASS

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The present study was undertaken to assess the feasibility and effectiveness of instruction that uses a structured cooperative learning technique in an upper level high school mathematics class. In addition, the study was designed to explore the nature of students' verbal interaction within this cooperative structure and how that interaction changes over time.

The term "cooperative learning" is applied to a diversity of instructional formats, but it typically involves two or more students interacting to learn academic material. Even though the methods differ in structure, they are all used with the expectation that doing so will increase motivation, more actively involve students with the material to be learned, promote higher achievement, and improve relations among students (Cuseo, 1990; Kagan, 1985). Results of research over the years, from the 1920s through the 1980s, have been consistent with these expectations for the achievement of academic, social, and personal goals (see Johnson & Johnson, 1974, 1989; Johnson, Maruyama, Johnson, Nelson, & Skon, 1981; Maller, 1929; Sharan, 1980; Slavin, 1978, 1980, 1983). Researchers and educators advocate the inclusion of cooperative learning in the educational system along with competitive and individualistic class structures (Damon, 1984; Kagan, Zahn, Widaman, Schwarzwald, & Tyrrell, 1985). Cooperative learning has been promoted as a successful teaching technique to cope with problems of achievement heterogeneity encountered when schools abandon academic tracking and when academically challenged students are mainstreamed (Slavin, 1985). Its use has even been mandated by some school districts and departments of education (e.g., California State Department of Education, 1985). Numerous professional organizations devoted to the study of cooperative learning have been formed (e.g., the International Association for the Study of Cooperation in Education, the Association for Supervision and Curriculum Development Cooperative Learning Network, and the American Educational Research Association Special Interest Group on Cooperative Learning), and the latest introductory educational psychology textbooks (e.g., Dembo, 1991; Good & Brophy, 1990) include lengthy discussions of cooperative learning techniques and effectiveness. Interest in its potential continues to grow.

Although the research to date has been very positive, what seems not to have been taken into account in the sweeping generalizations that have appeared in the literature are the differential effects due to different cooperative learning techniques, different subject matter, different grade levels, and different background characteristics of students (Kagan, et al., 1985). In their review of the research on cooperative learning and academic achievement in secondary schools, Newmann and Thompson (1987) cite widely different success rates for five different cooperative learning techniques, ranging from a high of 89% advantageous comparisons with controls for Student Teams-Achievement Divisions techniques to a low of 17% for Jigsaw. They note that most of the research has occurred in elementary schools and that there is a dearth of research in grades 10 to 12, especially. Only 6 of the 27 studies in their review were done in grades 10 to 12, and 4 of those were done in science. Only one dealt with mathematics at that level. There is ample evidence that high school teachers are less willing than others to use cooperative methods in their classrooms, thinking that they take too much time, do not work with their older and more sophisticated students, or create a chaotic classroom situation (Davis, 1985; Hibbard & Baron, 1990; Lake, 1986; Newmann & Thompson, 1987).

The study reported here addresses this need for research at the upper high school level and was designed to be a demonstration of the feasibility and effectiveness of using cooperative techniques with high school students. The participants of the study were 11th graders in an Algebra II/Trigonometry class.

Although there has been much research on the structural aspects of cooperative learning (e.g., goal and incentive structures, accountability), less attention has been given to the various other social and cognitive aspects. Some of the researchers who have been looking at these other aspects of cooperative learning have focused on peer interaction (see Webb, 1989, 1991). They found that a few kinds of verbal interaction were consistently related to achievement: giving content-related explanations (positive correlation), receiving a lower level of help than requested (negative correlation), and off-task discussion (negative correlation). Not only did verbal interaction influence learning, it appeared to be a mediator of the effects of student characteristics (e.g., ability, personality, gender) on achievement. Studies to determine what kind of interaction promotes higher achievement and what variables predict such interaction suggest that if verbal behavior can be changed through some sort of classroom intervention, then achievement could be increased. These researchers are looking for ways to manipulate group composition with respect to such variables as ability, gender, and personality in order to maximize students' achievement by providing optimum conditions for beneficial peer interaction. There are few such studies, however, that have examined the nature of peer interactions and their effect on achievement over time. Most studies have been only about two weeks long and with students much younger than those in grades 10 to 12.

There has been little field research on the effects of training students in interactions and behaviors believed to increase achievement in cooperative learning. Most research has just allowed students to interact "naturally" and studied what happened. However, structured interaction has been the focus of an extensive research program conducted by Dansereau (1984) and his colleagues (see O'Donnell & Dansereau, 1992). They introduced systematic manipulation of specific, theoretically-based learning and interaction strategies within dyadic studying situations in closely controlled laboratory experiments with college students. They devised scripts to specify the nature and timing of students' activities. Such scripts were designed to incorporate findings from cognitive and educational psychology by including such potentially effective activities as oral summarization (Ross & DiVesta, 1976; Yager, Johnson, & Johnson, 1985), metacognitive activities (Baker & Brown, 1984), elaboration (Reder, 1980), cross modeling and imitation of strategies (Bandura, 1971), and the use of multiple passes through material (Dansereau, 1985). The results of these experiments with "scripted cooperation" indicated that the script, either imposed by the teacher/researcher or generated by the participants, controlled the peer interaction and thus the achievement outcome. Results of their research program have been potent and consistent enough to warrant the use of dyadic studying in school environments (Dansereau, 1987; McDonald, Larson, Dansereau, & Spurlin, 1985).

For the present study, the theoretically-based text-learning script used in the "scripted cooperation" laboratory research was adapted to the needs and restrictions of a high school mathematics class. The newly-devised script was then used as the primary instructional technique for 8 weeks of instruction in a conventional Algebra II/ Trigonometry course for 11th graders. Achievement on the two chapter tests given over the experimental period was compared to the achievement of a comparable class of students who used the same textbook, tests, and teacher during the same period of time the year before. Achievement was examined for the periods before, during, and after the experiment and compared to relevant comparison-group performance in order to help answer the first general research question of the study:

> ***Research Question 1.*** *Can an effective program using dyadic studying techniques be designed for a high school course in higher mathematics (for instance, Algebra II and Trigonometry)?*

Students' interactions were tape-recorded numerous times over the course of the eight weeks of instruction. The tapes were transcribed and analyzed to help answer the second general research question of the study:

> ***Research Question 2.*** *When high school students are trained to use a dyadic studying strategy for learning from their text, what is the nature of their verbal interaction and does this interaction change over time?*

METHOD

Participants

Participants for this study were 11th grade students at a small, ethnically diverse laboratory school associated with a large university. The particular students involved in this study were the 56 students enrolled in the Algebra II/Trigonometry classes of two consecutive school years, called Year A and Year B for the purposes of this study. Both classes were taught using the same text materials and, except during the 8-week experimental period, the same conventional class structure and teaching routine. Year A served as the comparison group ($N = 30$) for this study and preceded Year B, the experimental group ($N = 26$). The two groups were comparable in ethnic and socio-economic background (which varied widely in both groups) and in general mathematics achievement, as indicated by their 10th-grade Stanford Achievement Test mathematics subtest results. The range of stanine scores on the SAT math subtest in both classes was from 5 to 9. Means were 7.33 and 7.54 for the comparison and experimental groups, respectively; the small difference was not statistically significant.

Instruments

Achievement measures. For both groups, algebra achievement was measured using the chapter tests provided in the textbook teacher materials. Tests were scored on a 100-point scale and in the same way for both groups, using a focused holistic scoring point scale that allowed partial credit for partial solutions (Randall, Lester, & O'Daffer, 1987)

Student characteristic measures. Instruments used to measure student characteristics included the Learning Preference Scale for Students (LPSS) and the Grade-10 Stanford Achievement Test (SAT). Experimental students took the LPSS (Owens & Straton, 1980) approximately 3 weeks before the study began and again right after the last experimental phase ended. The LPSS yields three scale scores relating students' preferences for cooperative, competitive, and individualized learning modes as three independent preference dimensions. Both groups' 10th-grade Stanford Achievement Test (SAT) scores were used as a measure of students' prior mathematics achievement. The test had been administered approximately one year prior to each group's treatment.

Post-experiment questionnaire. The day after the last experimental phase ended, students in the study filled out a 25-item questionnaire that used both rating scale and free-response formats.

Materials and Procedures

Textbook materials. Both the experimental and comparison groups used *HBJ Algebra 2 with Trigonometry* (Coxford & Payne, 1983), a standard textbook for college-track high school mathematics courses. The textbook format was conventional, similar to other textbooks on the market, and included the following: daily lessons consisting of an introduction then one or more elaborations of a concept, each followed by an example problem with correct solution, then a set of classroom exercises, and finally written exercises for homework assignments. The teacher edition provided chapter overviews, lesson-by-lesson commentaries, quick quiz problems to review the previous lesson, additional examples to supplement those explained in the student text, assignment guides, and answers to all the exercises. The Think-Aloud problems and Summary Questions on the follow-up worksheets used by the experimental group were usually drawn from the additional examples provided in the teacher edition as well as from the classroom and written exercises in the student text. The chapters of the textbook used for the direct comparisons in this study were selected because they contained new material on which students were unlikely to have had prior instruction. Topics included radical equations, quadratic functions, and imaginary numbers.

Student assignment to dyads. Students were assigned to dyads on the basis of personal preference and teacher discretion. Although some student preferences crossed gender lines, only same-sex dyads were formed to control for gender effects. On days when absences created an odd number of students, one triad was formed and the third member given a scripted role of observer.

Script development and use. For the experimental group, classroom learning sessions were structured by having students use a dyadic study script that prescribed certain activities and roles for the studying partners. The activities and roles specified by the script were based on empirical data from research with explicit learning scripts and on assumptions about learning strategies regarding rehearsal, elaboration, and metacognition. For example, to maximize interactions that involve giving and receiving substantive explanations, behaviors which have been found by Webb (1982) to correlate positively with math achievement, students were required to study the textbook examples of the algorithms being learned, then to take turns explaining them in detail, inserting the necessary intermediate steps to make their explanations clear to themselves and to their partners. (This role was labeled Explainer.) The receiver of the explanation (labeled Checker 1) was required to detect any errors and omissions in the explanation and to use questions to check the Explainer's understanding as well as to clear up any misunderstandings. This role was designed to engage the Checkers in active listening, which has been found to relate to achievement more than passive listening (Spurlin, Dansereau, Larson, & Brooks, 1984) and is a metacognitive activity shown to be effective for the initial acquisition of information (Larson, et al., 1984).

Right after the explanation of the first text example in their assignment, students used a worksheet provided by the teacher to perform two follow-up tasks to that example. The partner who first acted as Checker 1 used the worksheet to perform a Think-Aloud task, wherein the student solved a problem much like the text example while verbalizing all thinking about the problem. (The Solver role.) The previous Explainer's responsibilities during this phase were to continually check for accuracy and to demand constant verbalization. (The Checker 2 role.) As much as possible, Checker 2 was to let the Solver work through errors to self correction. If corrections were needed, however, they were to be done by using questions and prompts, not by just giving right answers. Whimbey and Lochhead (1982) as well as others have recommended that thinking aloud be used as a routine classroom exercise to teach problem-solving skills. Webb (1991) included in her list of suggested strategies that students might use to make their explanations to peers more effective that explainers assess others' understanding of how to solve a problem by giving them opportunities to solve problems by themselves, without interruptions.

The second follow-up task was called the Summary Question and was to be done by both partners working together. Whenever possible, the Summary Questions specified cooperative elaboration activities that required the use of the mathematical processes of reversibility, generalization, and flexibility, as described by Krutetskii (1976/1968) and which appear to further students' understandings of mathematical concepts. All work for the two follow-up tasks was recorded on the worksheet, and when the students finished the two tasks they switched Explainer and Checker 1 roles to do the second text example in their class assignment. The second example was also followed by two worksheet tasks that students then performed in the switched Solver and Checker 2 roles.

Students were required to switch roles across examples to provide both with the benefits of increased arousal produced by having to verbalize what they study (Hythecker, Dansereau, & Rocklin, 1988). Switching roles also provided both with the opportunity to observe the activities of another, providing for cross modeling and a chance to imitate successful strategies (Bandura, 1971). Figure 1 summarizes the four different roles and three different phases of the scripted learning experience.

The script was also a device to get students to engage mathematical text material to a much greater extent than they do under conventional teacher-dominated classroom structures, where the teacher usually presents all new concepts and operations to the whole class and the students' only required contact with the mathematics text material is with the assigned problem sets they do for homework. Use of the script required students to not only read mathematical procedures and reasoning but also to verbalize and communicate mathematical thinking using mathematical language and terminology. This allowed them to use a wider range of language genres than is usually required in a conventional math classroom (Marks & Mousley, 1990). This learning to read mathematical text material as well as some of the skills described previously might be expected to transfer to tasks beyond the experimental period, based on some of the "scripted cooperation" research reported by O'Donnell and Dansereau (1992).

Figure 1

Roles and Phases of the Paired-Learning Script

	PARTNER X	PARTNER Y
Phase 1	EXPLAINER Explains first textbook example.	CHECKER 1 Monitors explanation.
Phase 2	CHECKER 2 Monitors solution of problem.	SOLVER Works first Think-Aloud problem on the worksheet.
Phase 3	BOTH partners work together on the first set of Summary Questions on the worksheet, then SWITCH ROLES.	
Repeat Phase 1	CHECKER 1 Monitors explanation.	EXPLAINER Explains second textbook example.
Repeat Phase 2	SOLVER Works second Think-Aloud problem on the worksheet.	CHECKER 2 Monitors solution of problem.
Repeat Phase 3	BOTH partners work together on the second set of Summary Questions on the worksheet.	

The script was designed for use with a regular mathematics textbook in a program of instruction that fit into conventional school schedules (daily 45-minute class periods) and had typical requirements in terms of teachers, lesson preparations, subject-matter coverage, and classroom facilities. Specifically, the script was used by pairs of students during a period of approximately 20 minutes, following a teacher-led introduction to the lesson to be studied. Students had daily homework assignments that were accomplished outside of class. Questions on the previous day's homework assignment were generally handled during the beginning, teacher-led portion of the class period.

Training phase. The teaching of collaborative skills is a necessary part of implementing cooperative learning groups in a classroom (McGlinn, 1991), and the training used in this study took advantage of the suggestions of the practitioners as well as the findings of the researchers in this field (Johnson, Johnson, & Holubec, 1986; Palincsar & Brown, 1984). Students were initially trained in the use of the cooperative studying script over six class periods. Training included a rationale for the various activities required by the script; explicit instructions on the performance of the roles described in the script; live and videotaped demonstrations of the script in use; mediated practice of the individual activities and skills; monitored practice (using audio tape recorders and two observers) of the entire script in dyads, with feedback to the pairs; and a debriefing session to get student feedback and to solve unforeseen problems. During the training phase, mathematics material from an unrelated chapter (Chapter 14: Probability) of the regular textbook was used and students were tested on that material and on the roles and rationale for the cooperative learning procedure; the test was a take-home quiz consistent with the purpose of the training period to emphasize the scripted learning process rather than the mathematical content of the training materials. Informal training continued into the first experimental phase.

The formal training and subsequent experimental treatment phases occurred over an 8-week period at the beginning of the second semester of the regular school year.

Experimental phases. The experimental treatment period comprised two phases, the first 17 days long and the second 13 days long, each covering one chapter of the text (Chapter 8: Radicals/Quadratic Functions and Chapter 9: Complex Numbers/Quadratic Equations). During each phase, three to six student dyads were tape-recorded each day for three or four days at the beginning and then again near the end of the phase. Students were tested individually on the material, using a short quiz near the middle and a comprehensive chapter test at the end of each phase. Most class periods began with a 15-minute presentation by the teacher to the whole group; this included answering questions on homework and introducing the topic of the day's lesson. Students then worked in their assigned dyads for the last 20 minutes or so of each class period, processing the lesson material according to the studying script. A few class periods were spent in more teacher-directed variations of the script and others in testing. Provisions were made for each dyad to be recorded on at least three occasions spread over the 30-day experimental treatment period. In actuality, recordings were done more frequently than this in part to reduce the novelty of the recording situation and capture typical student discourse on tape and in part to compensate for the exigencies that always accompany research done in the field.

Before the training and experimental phases and for most of the time afterward, the experimental group was taught under a more conventional teacher-dominated classroom structure, like that of the comparison group the previous year.

Comparison group. Students in the comparison group also met daily for 45 minutes during the same period of the day as the experimental group. They were taught by the same teacher in a teacher-dominated classroom structure. The period generally began with a 10- to 15-minute review of the previous day's homework assignment, during which students often put their work on the board for the class to use for checking and discussing. Alternatively, the teacher began the class with the Quick Quiz problems provided in the teacher manual to review the previous day's lesson, and then she handled specific questions from the homework. The teacher then used the rest of the period to present the text lesson, which included demonstrating the solution to each text example problem as it was done in the text. After each example, the teacher wrote a similar problem from the teacher manual on the board for all students to work individually at their seats while she walked along the rows checking their progress. The teacher then demonstrated the solution on the board with step-by-step input from the students. Depending on the time available and the difficulty of the material, the teacher gave students another teacher manual-supplied problem or went on to the next textbook example. The homework review, new lesson presentation, and practice took most of the class period. At the end, a homework assignment was made from the written exercises in the student textbook. The comparison group covered the same chapters, Chapters 1-10 and 15, that the experimental group covered. For each chapter they took a quiz about half-way through and a chapter test at the end.

Post-experimental period. The experimental phases ended with the administration of the test for Chapter 9. During the post-experimental period, approximately the last quarter of the school year, the experimental group covered Chapters 10 and 15, the same as the comparison group. The classroom structure of the experimental group was like that of the comparison group except for a couple of days following a request by the experimental group to do the pair work again.

Verbal interaction variables. To determine the nature of students' verbal interaction and examine its change over time, several coding schemes were developed to describe and quantify data relating to students' fidelity to the script, their focus on the task, their cooperative behavior, and feedback to one another's help requests. The literature on small group interaction (Webb, 1991), informed the development of categories for this study but could not be directly applied because of the imposition of the script on students' natural interactions. For instance, all students gave explanations; they were a required part of the script. Thus categories for this study were designed to tap into behaviors that could be expected to affect achievement and where there was variance.

A three-part scoring scheme was devised to describe each student's fidelity to the script. Lines of transcripts of the audio recordings were coded as on or off task to assess students' focus on the assigned material. To assess cooperation, all requests for confirmation and checks for understanding (which were usually not distinguishable) were examined and feedback to them coded as agreement, disagreement, encouragement, or criticism. Unsolicited feedback in these categories was also coded and counted. Such requests and feedback were most evident in the interactions where one partner had a controlling role to play (as the Explainer or Solver). Since they involved checking with one's partner, they were considered indicative of cooperation. Sometimes one partner would usurp control of the interaction. These instances were coded as with or without the partner's consent. Other times when one partner was supposed to be in control, both partners shared control instead in a "guided" or "joint" production. Such productions were also common during the Summary Question phase of the script, wherein no controlling role was assigned. The number of instances of these categories of behavior was determined for each student.

Finally, feedback to direct and indirect requests for help (errors, statements of confusion, questions) was coded as follows: request ignored, request acknowledged but partner showed signs of hesitation or confusion, request responded to with a leading or probing question, request responded to with an answer or correction only, and request responded to with an elaborated answer (explanation). According to the work on task-related verbal interaction and mathematics learning in small groups (Webb, 1991) these request/response interactions were potentially instructionally significant exchanges. Prior research has shown that interactions wherein students received a lower level of help than they requested were consistently negatively related to achievement.

RESULTS

Experimental Versus Comparison Group

Two hypotheses were tested to answer the first research question regarding the development of an effective cooperative learning program for a high school math course: (1) The performance on chapter tests of the cooperative learning students is equal to or better than that of traditionally taught students; and (2) The performance on chapter tests of the cooperative learning students changes over time, as indicated by better performance on the post-experimental tests than traditionally taught students.

The graph in Figure 2 illustrates all the chapter test scores for the year for the experimental and comparison groups. Graphic analyses were followed with statistical tests that support the first hypothesis by showing under the structured cooperative learning program (the treatment) students in the experimental group performed as well as (Chapter 9) or better than (Chapter 8) the comparison group taught in a traditionally structured program (see Table 1). Statistical results also support the second hypothesis by indicating the performance of the experimental group changed over time (Chapters 10 and 15) as a function of the introduction of the structured cooperative learning program.

Figure 2

Experimental Group Test Scores Before, During, and After Instruction Using a Structured Cooperative Learning Program with Comparison Group Scores

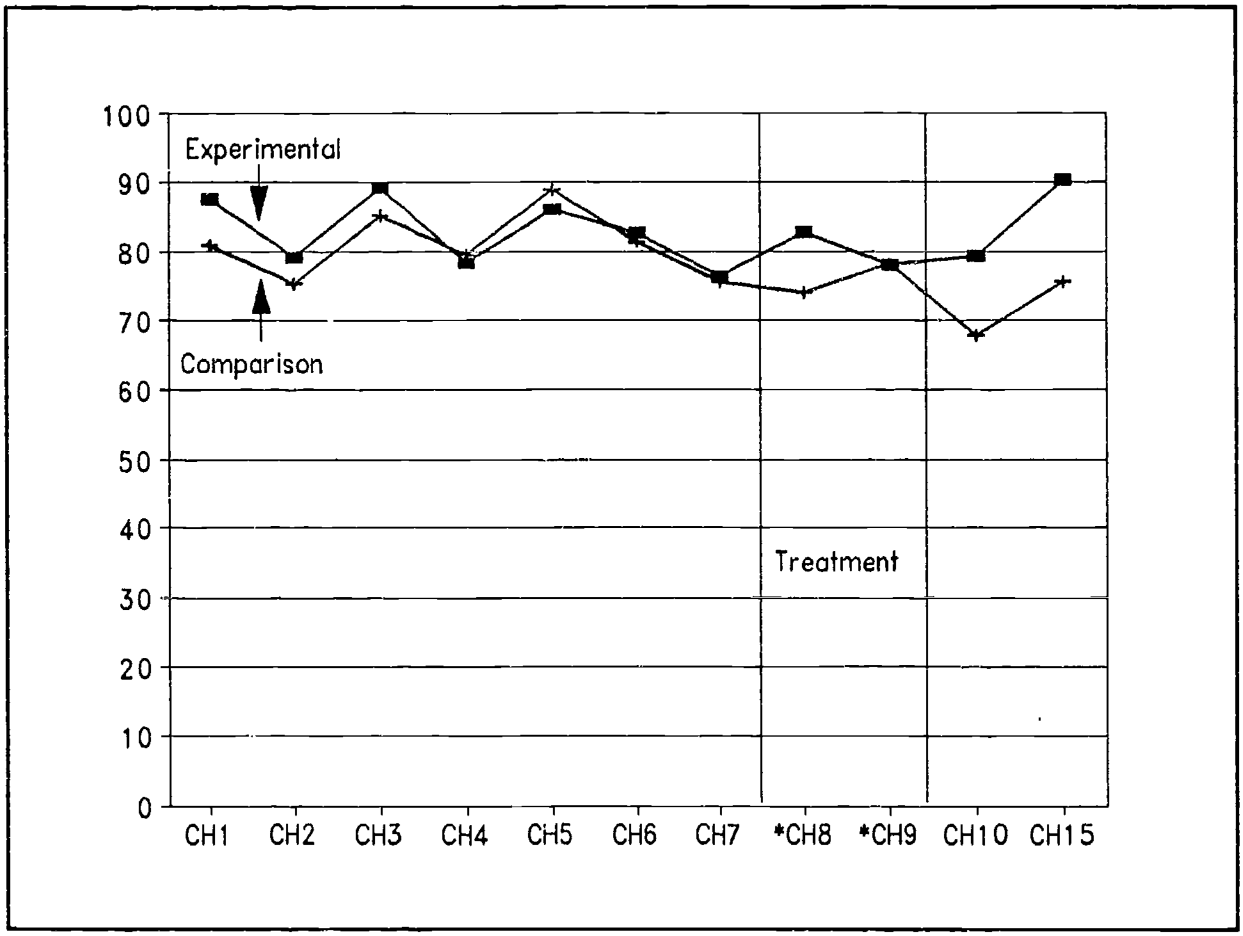

Table 1

Experimental and Comparison Group Chapter Test Scores

Group	Treatment Period		Post-Treatment Period	
	Chapter 8	Chapter 9	Chapter 10	Chapter 15
Experimental Mean *SD*	 82.89 16.99	 78.10 19.79	 79.35 15.73	 90.39 10.39
Comparison Mean *SD*	 74.10 18.00	 78.30 15.66	 67.80 20.02	 75.57 16.98
Difference of Means *t* *p*	8.78 1.87* .03	0.20 0.04 .48	11.55 2.37* .01	14.82 3.86* .00
Effect Size	0.49	0.01	0.58	0.87

*Statistically significant at α = .05, one-tailed, *df* = 54
MINITAB (1989) TWOSAMPLE procedure

The *t* ratio is acknowledged to be a remarkably robust test (Boneau, 1960; Runyon & Haber, 1984); consequently, tests for normality and heterogeneity of variance were not automatically applied to the data. However, an examination of the statistics in Table 2 prompted a question about the possibility of a dual effect for the experimental condition as indicated by the much larger standard deviations of the comparison group during the post-treatment period. Results of tests for homogeneity of variance (Runyon & Haber, 1984) showed only the difference in variances on the Chapter 15 tests was significant (F = 2.67, *df* = 29, 25). The smaller variance for the experimental group indicates fewer extreme scores at both ends of the distribution; a quick look at the raw data shows the reduction was mostly in extremely low scores.

In addition to the *t* ratios, effect sizes (the difference between experimental and control group test scores as a proportion of the control group standard deviation) were calculated for each comparison (see Table 2). Where there were statistically significant differences between test means, effect sizes ranged from 0.49 to 0.87, easily exceeding the criteria set forth in the rule of thumb (Tallmadge, 1977) for educational significance (effect must equal or exceed one-third of a standard deviation).

One other statistical analysis was conducted as follow-up to the graphic analysis; it involved the pre-intervention chapter tests. Using SPSS^{X} procedures suggested by Stevens (1990), an analysis of variance with repeated measures on one factor was performed on the test data from the first seven chapters (within-subject factor) for the two treatment groups (between-subject factor). Results are summarized in Table 2. As suggested by the graphic analysis, neither the effect for groups nor the interaction effect were statistically significant at the .05 α level. (As expected, there was a statistically significant effect due to chapters.)

Table 2

Summary of Analysis of Variance with Repeated Measures on Pre-Intervention Chapters (1-7)

Source		*df*	*SS*	*MS*	*F*
Between-subjects	55				
Groups		1	319.96	319.96	.39
Error-between		54	44600.26	825.93	
Within-subjects	336				
Chapters		6	7312.95	1218.83	15.37*
Interaction		6	904.23	150.71	1.90
Error-between		324	25690.09	79.29	
Total	391		78827.49		

*$p < .05$

To further address the question of the effectiveness of the cooperative learning program, two other analyses were done. First, a random selection of follow-up worksheets showed an average completion rate of 78% of answerable items completed with an average accuracy rate of 91% Second, evaluation of the responses to the take-home quiz given on day 6 of the training phase yielded 25 adequate descriptions of the Explainer role, 22 for the Think-Aloud Problem Solver, and 23 for the Checker on the 25 returned quizzes. In answer to the quiz question asking why the class was using the paired-learning script, 16 of 25 students gave rationales that closely paralleled at least one of the five reasons presented by the teacher on the first day of training. Eight students provided one or more reasons of their own. The most frequently cited (8 students) teacher-provided reason involved the development of study skills, that is, to learn how to learn so you become an independent learner, capable of reading a math textbook on your own. The most common student-provided reason (7 students) was that it encouraged learning from your fellow students instead of always having the teacher explain, since you learn better sometimes from someone your own age who speaks your language.

Nature of Verbal Interaction and Change Over Time

Fidelity to the script. The analysis of the transcripts for 11 dyads sampled over three days in the middle of the experimental phases of the study showed that 12 of the 22 students fully played their roles as described in the script (role-fidelity scores of 100%), 6 of them played three of the four roles as prescribed (scores of 75%) and 4 of them played only two of the scripted roles with fidelity (scores of 50%). Of the 10 students who departed from the scripted roles, most of them failed to play Checker 2 as prescribed. Usually they were too quick to fill in answers for their Think-Aloud problem solver partners. The four students with only 50% fidelity to the script acted in joint production roles, where they both hammered out the explanation of an example and together crafted a solution to the Think-Aloud problem.

Only 1 of the 11 dyads did the activities out of their scripted order. They did the two Examples first then the two Think-Aloud problems, but they played all of the roles. Three dyads altered their role/activity assignments. In two dyads the same person explained both examples, while her partner played Checker 1 both times. In the other dyad the Explainer for the first Example also played Solver for the first Think-Aloud problem. They did the activities in the scripted order, however, and had role-fidelity scores of 100%.

In all 11 dyads both students were actively involved with the text and worksheet material, even though they did not always restrict their involvement to that called for by the script. The most common departure from the script was with the Checker 2 role, and that was overplayed rather than underplayed in each case. In a couple of dyads the less able partner (as measured by SAT-math scores and/or first-quarter course grades) often deferred to the more able one, in some cases inviting the more able partner to overplay the checker roles. In these same dyads the more able partner would sometimes ensure the success of his less able partner by volunteering to do the harder of any two activities, leaving the easier one for his partner. As mentioned earlier, in two of the dyads one of the partners did both explanations; it was implied by their dialogue that that partner was the one who understood better what was being done in the example.

Further information on the usability of the script was obtained from the post-experiment questionnaire, wherein responses indicated that students found the script to be relatively easy to use (average response 2.0 on a 5-point scale where "1" was "easy to use" and "5" was "difficult to use") and tended to help them learn the material (average of 2.2 where "1" was "helped me learn the material" and "5" was "made it more difficult to learn the material"). One other piece of data is helpful: teacher interventions occurred in only 5 of the 11 transcripts analyzed. Four interventions were prompted by student requests for assistance. In only one case did the teacher intervene uninvited to get students back on task and monitor their progress.

Focus on the task. To determine whether or not students' verbal interactions were focused on the task, the 11 transcripts were coded and analyzed to develop percentages for on- and off-task interactions. The transcripts were from three different lessons and the source tapes averaged about 16 minutes in duration. Scripted interactions averaged about 230 lines of transcript of which an average 216 lines (94%) were focused on the task and an average of 14 lines (6%) included off-task behavior. Individual students ranged from highs of 100% on-task verbal interaction to a low of 79% on-task interaction. Most off-task interactions were of very short duration and did not seriously interrupt the students' work. Except for the dyad with the low rate of 79%, all ten other dyads were focused on the task for at least 89% of the lines of their transcripts.

Cooperative behavior. Indicators from the transcripts, data from the post-experiment questionnaire, and scores from the LPSS were used to help determine how dyads varied in their degree of cooperative behavior. Three listeners to the taped dyads commented on how cooperative the students in this study were with each other. There seemed to be little or no teasing or criticism; there was much good humor and laughter. Although some students were obviously more awkward than others playing roles, most of them played along quite well. Most students provided their partners with lots of "uh huh" and "okay" remarks during their explanations, which were interpreted as indications that they were listening to and agreeing with what was being said. Rarely were direct questions unanswered, and partners seemed to frequently check on one another's understanding. Some higher-achieving students were often remarkably accommodating of their lower-achieving partners, providing prompts and guiding them in solutions to problems instead of taking over to get the assignment done. Some students established more of a tutor-tutee relationship for parts of their interaction. Other, more closely matched students worked in tandem, often finishing one another's sentences in what could be called "joint productions." The general impression of the listeners and transcribers was that the students were positive and very cooperative with the program requirements and with one another. Two analyses of the transcripts helped define the dimensions of this cooperative behavior and validate the listener/transcriber impressions.

Transcripts were coded for all requests for confirmation and checks for understanding, which were often one and the same, along with their responses. This feedback fell into four categories: agreement, which included statements of understanding; disagreement, which took the form of both statements and questions; encouragement; and criticism. These four kinds of feedback were also proffered by students to their partners without any direct verbal solicitation. Since it fit the pattern of the interaction being examined and was perhaps implicitly solicited, this apparently unsolicited feedback was included in the coding. Table 3 contains the frequency data for this analysis.

Table 3

Frequency of Interactions: Agreement, Disagreement, Encouragement, and Criticism

Dyad	Student	Total Requests Made[a]	Solicited Feedback Given					Unsolicited Feedback Given			
			All	A[b]	D[c]	E[d]	N[e]	A[b]	D[c]	E[d]	N[e]
1	a (B)[f]	6	1	1				3	1		
	b (B)	1	5	3	2			3			
2	c (B)	4	10	9	1			41	4		
	d (B)	12	4	3		1		9	9		
3	e (A)	5	7	6		1		13	2	5	
	f (C)	7	5	5				4			
4	g (B)	9	12	10	1	1		16	2	1	
	h (C)	13	9	7	2			13	3	1	
5	i (C)	3	11	4	6		1	5			2
	j (C)	12	3	3				5	4		
6	k (C)	3	4	3	1			1	4	1	
	l (C)	11	3	3				8		4	
7	m (A)	6	9	9				38	4	3	
	n (A)	9	6	6				25	1	2	
8	o (A)	16	9	8	1			12	1		
	p (A)	11	15	14	1			18			
9	q (A)	6	10	9	1			13	1		
	r (A)	16	4	4				14	1	2	
10	s (A)	4	14	14				11	1		
	t (C)	14	4	4				17	1		
11	u (A)	16	9	7	2			6	1	1	
	v (B)	11	11	9	2			10	1		

[a] Explicit requests for confirmation, checks on partner's understanding, or both.
[b] Agreement, understanding, or both.
[c] Disagreement or misunderstanding in statement or question form.
[d] Encouragement or praise (beyond simple confirmation).
[e] Negative criticism (devoid of praise or encouragement).
[f] First-semester grade in course.

The data in Table 3 support some of the listeners' impressions. Direct questions rarely went unanswered (and those that did could have been answered nonverbally with head shakes). There was almost no criticism of partners. The 3 negative remarks among the over 500 remarks categorized were all made by the same individual, who was, in his defense, attentive to his partner, responding verbally to 11 of 12 partner requests for confirmation/understanding. A large proportion of his responses were disagreements (6 of 11), but these may have less to do with cooperative behaviors than with this student's misunderstanding of the mathematical material being discussed. Finally, students seemed to be very attentive to one another, as indicated by the numerous unsolicited responses indicating agreement and/or understanding. These averaged almost 13 per student. The majority were one-word agreements like "okay" uttered during their partner's performances of the Explainer or Solver roles. Such utterances could also be interpreted as encouragements to continue, although there were also more obvious encouragements and praise such as "It's not hard, you can do it" and "Just keep on talking . . . you're doing it right." Some dyads' relatively low total of requests and responses must be considered along with the results of the next analysis, which looked at another kind of interaction that usually occurred when neither partner was playing a controlling role.

"Joint" and "guided productions" and attempts to usurp controlling roles were analyzed as part of the examination of cooperative behavior. (See Table 4.) These categories were usually applied to a series of interactions surrounding the solution of a specific problem or performance of a task specified by the script and follow-up worksheets. When students followed the script, formal control of the interaction alternated among three situations: (1) the Explainer in control, then (2) the Solver in control, and then (3) neither formally given control for the Summary Questions. In this analysis, usurpation was considered cooperative behavior when it happened with the partner's consent, as when the student who was supposed to be in control was too confused to effectively perform the role and implicitly or explicitly relinquished control. This sometimes resulted in a complete exchange of roles. Other times it resulted in a "guided production"—the Checker would take control of the executive functions of the problem-solving process and guide the partner through the mechanics of the solution. Usurpation of control, or attempts at it, without the partner's explicit consent were usually considered uncooperative. This seemed to occur most often when the Checker for the Think-Aloud Problem Solver interjected himself too much into the problem-solving process. "Joint productions" occurred most often during the Summary Questions and when both partners had an equal grasp of the material, which was not necessarily a full understanding of it. In joint productions students seemed to take turns vocalizing the solution steps of the problem, often finishing one another's sentences, talking simultaneously, or echoing one another. On a few occasions the Explainer or Solver got bogged down and asked for help, prompting the Checker to step in. But rather than usurping total control, the Checker often just shared control in what became a joint production. Figure 3 contains an example of a joint production by students "s" and "t." Dashes represent undecipherable utterances, and the quoted lines were read word-for-word from the worksheet Summary Questions. Unlike many joint productions, there is no simultaneous speech in this one.

Table 4

Occurrence of Control Changes, Joint and Guided Productions[a]

Dyad	Student	Usurped Control		Guided Productions	Joint Productions
		W/out Consent	W/ Consent		
1	a (B)[b]	SQ1			
	b (B)				
2	c (B)		SQ1a TA2 as C2	(TA2 as C2)	SQ1a+[d] SQ1b TA2+[d] SQ2+[d]
	d (B)	TA1 as C2[c]	SQ2		
3	e (A)		SQ1a SQ1b	SQ2a SQ2b	(TA2)
	f (C)		TA2 as C2		
4	g (B)				SQ1b TA2+[d] SQ2a SQ2b
	h (C)		SQ1a EX2 as C1	(EX2 as C1)	
5	i (C)	TA2a as C1[e] SQ2a SQ2b			SQ1a SQ1b
	j (C)				
6	k (C)				
	l (C)		TA1a as C2[e] SQ1a SQ1b		

Table 10 (Continued)

Occurrence of Control Changes, Joint and Guided Productions[a]

7	m (A)				SQ1b SQ2a SQ2b
	n (A)		SQ1a		
8	o (A)				SQ1a SQ1b SQ2a
	p (A)				
9	q (A)	TA2 as C2			SQ1 SQ2 (TA1a) (EX2)
	r (A)		TA1a as C2 EX2 as C1		
10	s (A)		TA2a as C2 TA2b as C2 TA2c as C2		(TA2a) (TA2b) (TA2c) SQ1 (TA1a) (TA1b)
	t (C)		TA1a as C2 TA1b as C2		
11	u (A)		TA1a as C2 TA1b as C2 SQ1a SQ1b EX3 as C1	(TA1a as C2) (TA1b as C2)	SQ2a SQ2b
	v (B)				

[a]Key to symbols: EX = Example
TA = Think-Aloud problem
SQ = Summary Question
C1 = Checker 1 (checker for the Explainer)
C2 = Checker 2 (checker for the Think-Aloud Problem Solver)

[b]First-semester grade in course.
[c]Unsuccessful attempt.
[d]Elaboration of the topic beyond the text and worksheet after the problem was solved.
[e]Returned control to partner for part b.

Figure 5

Example of a Joint Production

s. "Show why the axis of symmetry is x equals negative 3 for this parabola y equals x squared plus 6 x by setting y equal zero, by setting y equals zero and following the" direction, what is that?
t. *Derivation.*
s. "the derivation in Example 1."
t. *Oh. See it's saying y equals C, right?*
s. Yeah.
t. *So x squared plus 6 x equals zero.*
s. Yeah.
t. *You factor for x.*
s. Yeah.
t. *x plus 6. equals zero. So x equals zero, by*
s. —
t. *— doing this, okay?*
s. Okay.
t. *How 'bout — gonna work backwards, right?*
s. Yeah, you know that x is negative 3.
t. *So that'd be negative 6, right? And this'd be y, wait, that'd be 2, right? Cause the negative 3.*
s. Yeah, okay. That's it.
t. *Right?*
s. Okay.
t. *Okay.*
s. You gotta minus the 6. x plus 6 equals zero, yeah, so put, can put the six on the other side. Minus 6 on the other side.
t. *Oh, — —*
s. One more step
t. *x equals 6.*
s. Negative 6, cause you minus 6 from both sides, right?
t. *Okay.*
s. Okay. I have to explain now. This is example 2. Okay. You have to first

To summarize the results of the transcript analyses for variations in cooperative behavior, there were variations in the kinds of cooperative roles that emerged and there were differences in the degree of cooperation between students in the dyads. The kinds of cooperative roles seemed to be defined by the relative equality of the partners in terms of their understanding of the material, with the tutor-tutee relationships on the one extreme, moderate understanding by both partners in the middle, and a firm grasp of the material by both partners at the other extreme. Most students seemed to accommodate their partners' strengths and weaknesses, playing model, guide, monitor, equal, or tutee, as required. The variation in the degree of cooperative behavior was an indication of how well individual partners accommodated themselves to the roles that their situations indicated. The students who usurped control without their partners' consent either misjudged or were unwilling to accept roles as monitors of or equals with their partners in those particular tasks. The students who usurped control with the partners' consent were being very cooperative, taking cues to help a partner who was in trouble or who preferred playing the role of tutee with an accommodating tutor.

Looking at all the changes in control listed in Table 4, it is striking that most of them were instructionally positive takeovers, that is, usurpations of control with consent or guided productions. Of the 32 total changes, 24, or 81% or them, were instructionally positive. Of the only 6 negative takeovers (without consent), 3 of them were done by the same student.

Responses on the post-experiment questionnaire wherein students rated their attitudes about studying with a partner averaged 4.1 on the 5-point scale where "1" was "negative" and "5" was "positive." The lowest rating given was a 2, slightly negative, by three females. Their pre- and post-experiment scores on the LPSS cooperative subscale were consistent with this low rating: they all scored below the class means of 32.9 and 33.1 for one or both scores. The data in Table 5 show that overall students had scores on the cooperative subscale of the LPSS that were considerably higher than those on the individualized and competitive scales. As table 5 indicates, there were no statistically significant changes in mean scale scores from the pretest to the posttest, however the ANOVA results, using CSS: STATISTICA procedures for analysis of variance with repeated measures (StatSoft, 1991), indicated a statistically significant effect for the scale factor (F = 28.842, df = 2/46, $p < .01$). Subsequent Scheffé tests showed statistically significant differences ($\alpha = .01$) between students' mean score on the cooperative preference scale and their means on both the individualized and competitive scales; the difference between students' mean scores on the latter two scales was not statistically significant.

Overall, LPSS scores and questionnaire responses supported the impression that students were very cooperative. Given their high pre-experiment scores on the cooperative subscale, this did not seem to be a function of the paired-study program. The program, however, was a positive enough experience that post-experiment scores on the cooperative subscale remained high and even increased a bit, though not significantly. Means on the individualized and competitive scales remained lower. Students had a marked preference for cooperative situations that was evident in their LPSS scores and in their taped interactions.

Table 5

Scores on the Learning Preference Scale for Students (LPSS)

	LPSS Subscale Scores[a]					
	Individualized		Cooperative		Competitive	
	Pre	Post	Pre	Post	Pre	Post
Mean (N=24)	26.7	25.6	32.9	33.1	27.2	28.0
SD	3.6	3.6	3.7	3.6	4.5	4.4
F	3.711		0.095		1.313	
p	.066		.761		.264	

[a] Three 10-item subscales; 40-point maximum, 10-point minimum on each.

Feedback to 'elp requests. According to the work on task-related verbal interaction and matuematics learning in small groups summarized by Webb (1991), some of the most instructionally significant exchanges were those begun by one student's request for help. This study looked at what happened after direct and indirect requests for help that took the form of questions about the problem at hand ("Where does the zero come from?"), direct requests for explanations or other assistance ("I need an explanation, please." or "How do you do that?"), statements of confusion ("I guess I don't understand what they mean by congruent."), statements of disagreement ("No they won't." or "Wait."), and errors. One of the ten strategies Webb (1991) suggested might be useful for students working in small groups addresses statements such as these. Her suggestion is to "respond to all indications of misunderstanding or incomplete understanding (errors, statements of confusion, questions) with elaborated descriptions instead of brief responses or only the correct answer" (p. 385).

Since the script called for students to give explanations to one another for at least two thirds of their tasks, these students received elaborated descriptions whether they asked for them or not. Most of the explanations in the transcripts were not prompted by direct or indirect requests for help. Nonetheless, within this context of rather constant explanation, there were requests for help, questions inviting further explication of the topic, and errors. The direct and indirect help requests were coded, and the responses to them were categorized as follows: request ignored, request acknowledged but partner showed signs of hesitation or confusion, request responded to with a leading or probing question, request responded to with an answer (or correction) only, request responded to with an elaborated answer (explanation). Table 6 contains the total tallies for these help request/response exchanges.

Table 6

Frequencies of Help Request/Response Exchanges

Dyad ID		Direct Request or Question					Statement of Confusion					Statement of Disagreement					Error				
		I	M	Q	A	X	I	M	Q	A	X	I	M	Q	A	X	I	M	Q	A	X
1	a				2	2														2	
	b		1		1			1												1	
2	c			1		1				1					3		1		1		
	d		2			2					3				2	3	1				1
3	e																				
	f				3	1		1	2	1	7					1			1	1	
4	g									1	1		1			1	3	2		1	
	h					2							2				1	1	1	1	
5	i					1					1		1		1		1	1	5		
	j				1	1	1		1	1	4			1			1		2		
6	k				3	3									1	4			1		
	l					2															
7	m		1		1	1									1	1	2				
	n		1	1	1	1		2								1			2		
8	o				1											1					
	p				1	2			1		1							1			
9	q		2		3	8		1								1	1	1	1		1
	r			1	1	4	1	2					1				3				
10	s					2											2			1	
	t					4		1												2	2
11	u				1			1									2		1	1	
	v		1			1										2	1		1		
Totals		0	8	3	19	38	2	9	4	4	17	0	5	1	8	15	19	6	16	10	4
Percents		0	12	4	28	56	6	25	11	11	47	0	17	3	28	52	35	11	29	18	7

I = Request (statement/error) ignored.
M = Request (statement/error) acknowledged, partner showed hesitation/confusion.
Q = Request (statement/error) responded to with a leading or probing question.
A = Request (statement/error) responded to with an answer/correction only.
X = Request (statement/error) responded to with an elaborated answer/explanation.

As Table 6 shows, no direct requests for help or statements of disagreement were ignored. In both cases they were responded to over 50% of the time with elaborated answers (explanations). Over 80% of the time they prompted some kind of answer, either an unelaborated one or an explanatory response. Most of the rest of the time the requests and disagreements were met with mutual confusion or hesitation. Almost 50% of the statements of confusion were responded to with explanations. A quarter of them prompted acknowledgment coupled with some sign of mutual confusion from their partners. These mutual confusions often accompanied joint productions, which occurred most often during the Summary Questions, where the script made no controlling/explaining role assignments and the questions were usually extensions of the topic rather than direct applications of it.

About 20% of the errors that students made were corrected by their partners providing just the right answer with no elaboration. Fewer than 10% of errors prompted elaborated answers. At first blush, this seems to be disturbingly at odds with Webb's (1991) suggestion. But, interestingly, given the instructions to students to not give answers when playing the role of Checker but to use questions instead, students responded with leading questions to about 30% of the errors. At least as many errors as were questioned were ignored, however, about 35%. In some cases they actually were ignored because they were minor, slips of the tongue, misuses of new terminology, or misstatements that did not affect the progress of the problem solution or explanation. In several cases, however, the errors were not purposely ignored but went undetected by either partner and were major errors that resulted in incorrect answers to problems and misconceptions. In at least two of these cases the teacher was called upon for help and pointed out students' mistakes. In other cases, students checked the chalkboard for the correct answers, and they caught their own errors. Not all misconceptions and errors were detected and corrected, however.

Changes over time. Four dyads were selected for analysis over time, two female dyads and two male dyads. In all four of these dyads students played all roles with moderate to high degrees of fidelity to the script and they represented the different ability pairings that occurred in the 13 dyads in the class. Comparisons were made of representative samples of discourse behavior for the chosen dyads over three occasions spanning the beginning, middle, and end of the treatment period. The same coding schemes described previously were used on these transcripts: ratings for fidelity to the script; coding for off-task interaction; categories of cooperative behavior including requests for confirmation/understanding and control of interactions; and the kind of feedback given after direct and indirect requests for help.

In addition to the transcript analyses, all students' answers to the post-experiment questionnaire were tallied. When asked about whether or not they had changed the script in any way, students indicated on average they made "some" changes. When asked to describe their changes, 19 of the 26 students in the group described some change. Several reported changes in their initial preparation for playing the roles; some dyads said they worked the Think-Aloud problems together. In some dyads the person who understood the topic better started the explanations and sometimes did them both. One dyad would skip the explanations and go right to the worksheet; another did the worksheet first, then went back and did the explanations if there was time. Others reported they would both help out in explaining everything, relaxing the roles, as one student put it, "melding the two into one." Others reported not being thorough in explanations, going on even when they were confused, or changing the assignment of activities to accommodate a partner who needed more practice.

In general, the changes in interactions over time included an adjustment to the artificiality of playing roles and of being taped, a softening of the distinction between the roles for some dyads, more frequent off-task interaction for those who tended to it initially, and perhaps more strain in dyads where the initial cooperation was least.

DISCUSSION

Effectiveness of the Program

Results of the statistical analyses supported the research hypotheses regarding the short- and long-term effectiveness of the structured cooperative learning program developed for this study. Those hypotheses suggested that the achievement of students using the paired-learning technique would be at least as high and possibly higher than that of a comparable comparison group. In three out of the four comparisons, the cooperative learners achieved more than the comparison-group students; in one comparison there was no significant difference. The program seemed to have shown itself to be at least as effective as a more conventional instructional method, as measured by chapter test scores.

But effectiveness is not the only criteria by which instructional programs are judged by those who must implement them. Other criteria must be considered before declaring the structured cooperative learning program a promising one for standard high school Algebra II/Trigonometry courses. The objections of high school teachers to using cooperative learning must be countered. In addition, the following general implementation requirements must be sufficiently met. Material must be covered at a pace equivalent to a conventional course. Demands on the teacher for special expertise, class preparations, or paper grading must not be excessive by conventional standards. Students must enjoy doing it, or, at the very least, not oppose doing it. Excessive training should not be necessary for teachers or students. Special materials should not be required.

Part of the purpose of this study was to demonstrate that scripted cooperative learning could be done easily, using existing text materials, within existing time schedules, and without much, if any, additional preparation or grading time by a conventionally-trained teacher in a high school mathematics class. In addition, the results were expected to show that upper-level math students liked doing scripted cooperative learning and benefitted from it. Most of the implementation criteria listed previously were met by the program devised for this study. Regular textbooks were used. The same material was covered in the same amount of time as done by the comparison group; these schedules followed the suggested time lines provided with the text. The worksheets that were distributed each day were devised during normal lesson planning time from material provided, for the most part, in the teacher manual. Some of the Summary Questions were invented by the teacher by following general guidelines for providing experiences with the mathematical processes of reversibility, generalization, and flexibility (Krutetskii, 1976/1968); this is an activity well within the abilities of an experienced math teacher.

Six days were used specifically for training, but some math content was also taught along with the scripted cooperation procedures. The only training requirement for the teacher would be that he or she become knowledgeable enough about the script to model the roles for students and to justify the activities required by them. In this study, the effects of training could not be separated from the effects of using the script. It is assumed that the training contributed substantially to the successful use of the script initially and to the sustained use of it over time (by providing a strong rationale that appealed to these generally college-bound students' desire to improve their study skills and become more independent learners).

Student responses on the post-experiment questionnaire reflected an overwhelmingly positive reaction to the paired-learning experience, although after eight straight weeks of its use exclusively, some of them said they would prefer to do it a little less often than five days a week. From a teacher's perspective as well, it would be better to use the scripted cooperative technique along with other instructional methods. For the dyadic studying sessions to succeed, the role of the teacher must change from what it normally is in a more conventional, teacher-centered class; the teacher must be very low key during class and have worked out all of the management details beforehand for the class to run smoothly. She must make herself unessential and unobtrusive, providing instructions and correct answers where students can get them without her help and letting students work out problems on their own, intervening only when asked. This way the cooperative learning classroom works; students stay on task and order prevails. Since many teachers do not want to let go of their conventional teaching role altogether and students tire of the same instructional routine day after day, using a variety of instructional strategies, which includes scripted cooperative learning, is a good idea. Either way though, as the primary instructional strategy or as one of several, the scripted cooperative learning strategy devised for this study can be an effective instructional program in a high school mathematics class.

Role of the Script

The script was the key element of the dyadic studying technique devised for this experiment. The activities called for by each of the four roles (Explainer, Checker 1, Solver, and Checker 2) were based on theories about cognition and study strategies. One of the three phases of the script was purposely left unstructured in terms of student roles to see how it would be handled. The effectiveness of the program was due, in part at least, to the nature of the script and how it was used by students.

Judging from the taped interactions, students were remarkably faithful to the script, even over time. They rarely skipped activities, and did most of them according to the role requirements. One role was more frequently altered than any of the others: the Checker 2 role. Scripted opposite the Think-Aloud problem Solver role, it was the most difficult for students to perform. They often overstepped the monitoring role of the Checker 2 and participated in the problem-solving activity. This changed the activity from one wherein the first student was allowed to solve a problem alone to test his understanding of the process while the second student was allowed to observe someone else's thinking process. It became in some ways an easier activity for the Solver when the Checker helped with the problem, making it a "joint production." In some cases, in fact, that was the only way the Solver could do it. The Checker 2 was instructed to not give answers when the Solver made an error, but to instead ask leading questions to help the Solver discover and correct his own errors. This proved very difficult for many students to do. Since this role was the most often altered in practice, the role of Checker 2 needs to be reconsidered.

Perhaps the most interesting and promising interaction examined in this study was the joint production. As indicated earlier, joint productions were often chosen or resorted to during the Think-Aloud problem solving activity. They occurred most often, however, during the Summary Questions, when no controlling role assignments were scripted and students were left to their own devices as to how the two of them would perform the work required to answer the questions. During joint productions students seemed to work in tandem and were almost of one voice, talking together or alternating the vocalization of their work and idea generation. They seemed to occur when partners were at the same level of understanding and not necessarily when they both understood the topic well. Joint productions might be interpreted as both students giving an explanation, and, since they are thinking along the same lines, they both give and receive immediate feedback at a level of elaboration that closely matches what their partners need. It is highly responsive interaction. Interpreted this way a relationship of joint interactions to achievement would be consistent with the literature on small-group interactions wherein giving explanations has been consistently related to achievement (positive) and receiving explanations has been sometimes related to achievement (positive, but not significant).

One other thing the script did that may have had a long-term effect on students' study skills has to do with processing text. The text in mathematics books is very dense and peculiar, unlike much of the text material high school students deal with in social studies or English class, for instance. Where students can often comprehend most of the ideas in a social studies text passage by skimming it and skipping over parts, such habits spell doom when used to read mathematics textbooks. In this teacher's experience, students tend to skip the "number stuff" and only read the words. They often skim the equations and simply ignore symbols they do not recognize. They are unused to rereading passages several times to derive their meaning. Usually, such shortcomings in math text processing skills have little effect on students' achievement, because their teachers demonstrate and explain to them the concepts contained in the text. The students rarely deal with the text material beyond the problem sets given as homework.

In the paired-learning script role of Explainer, students were required to go through the math text material line by line, reading the equations with all of their symbols, and explaining what procedures had been done from step to step. During the initial training for using the script, the nature of math text material was discussed and some general guidelines given for reading it: never skip over the equations; figure out what every symbol means; expect to read each passage at least three times. The training and experience of having to read mathematics text material may have been a factor in the boosted achievement of the experimental group over that of the comparison group on the two chapter tests taken after the scripted cooperative learning ceased to be the primary instructional technique used with the class. During the post-experimental period the teacher again demonstrated and explained to the class all of the procedures and concepts in the text material. Those who did not completely understand the class presentations, though, may now have had an additional skill to help them learn the material on their own from the text. There is some possible evidence for this effect in the differences between the experimental and comparison groups' variances on the last two chapter tests (Chapters 10 and 15, done during the post-experimental period). Standard deviations were 15.7 and 10.4 on the two chapters for the experimental group compared to 20.0 and 17.0 for the comparison group (refer to Table 1). The difference between the latter variances was statistically significant ($\alpha = .05$), indicating that there were fewer extreme scores in the experimental group than in the comparison group. Not only was the mean higher for the experimental group on this test of Trigonometry concepts and skills, but achievement appeared to be more homogeneous than it was in the comparison group, perhaps due in part to delayed effects of using the paired-learning script.

Nature of the Verbal Interaction

Listening, while transcribing, to the audio tapes recorded during the scripted cooperative learning sessions, one was struck by the warm, frequently joyful, cooperative nature of the dyadic interaction. The coded transcripts provided evidence that the climate was non-negative and supportive, judging from the very low frequency of critical remarks made and by the high frequency of solicited and unsolicited confirmations. Students were generally very attentive to one another, and frequently very accommodating, with higher-achieving students readily offering their support, both moral and academic, to their partners while they explained and practiced new math skills. High pretest scores on the cooperative scale, relative to the individualized and competitive scales, of the LPSS learning preference measure indicated that this group was for the most part predisposed to enjoy working together in a cooperative class structure. The even higher posttest scores on the same scale indicated, as did the students' responses on the post-experiment questionnaire, that they did enjoy the scripted dyadic learning experience. Further evidence may be the near significant ($p < .066$) decrease in scores from pretest to posttest on the individualized scale of the LPSS and the lack of any increase in the already low competitive scale scores.

In spite of the sometimes frequent laughter and rather joyful play acting of the roles, students' interactions were remarkably focused on the academic task. Transcript analyses revealed that overall about 94% of all the lines of the transcripts were focused on some aspect of the academic task. Although a count was not made, the reader's impression was that very few of those on-task lines dealt with management of the task; they were focused on explaining, problem solving, or seeking confirmation during one of those activities. Although a direct comparison to time cannot be made, it is informative to know that some of the "time-on-task" studies of several years ago found widely variable rates of time on task depending on the classroom setting (Good & Beckerman, 1978; Fisher et al., 1980). The highest rates were found during small-group work (82%), and the lowest rates during whole-class activities (66%); students working alone were somewhere in between (71%) (Good & Beckerman, 1978).

Understanding Interactions under Scripted Learning Conditions

Under the scripted learning condition, questions were often not really questions, but attempts by the Checker to get the Explainer to elaborate more or to get the Solver to catch an error. Explanations were not given just by those who knew the material well, but by everyone when performing the Explainer and Solver roles. The script altered what would have been the "normal" interaction and made it difficult to apply what is known about small-group interaction from the literature. For instance, the importance of giving explanations is probably underestimated in the present study. Only the explanations students gave in response to direct or indirect requests for help were coded and counted in the transcript analysis. The formal explanations given by students playing the roles of Explainer and Solver were not included in the analysis, and from a theoretical perspective, giving and receiving these explanations could be expected to promote understanding and increase achievement. According to theories of the social construction of knowledge (e.g., Doise & Mugny, 1984; Vygotsky, 1978) an individual's understanding is facilitated through peer interaction during which differing individual perceptions arise and are reconciled. These differing perceptions can be as simple as a difference in the amount of information two people have to clearly opposite and conflicting viewpoints. The resolution of such "sociocognitive conflicts" results in the social construction of knowledge. In this study, Explainers and Solvers were required to externalize their thoughts, making their thinking accessible to their partners as well as to themselves. This would frequently expose students to differing perspectives on the topic under study; they would be compelled to think about it in new ways and to reconcile the multiple views, thus to construct new knowledge or transform old knowledge into new.

Joint productions can also be considered in such a theoretical context. They often occurred when students were at about the same level of understanding but not necessarily when they both understood the topic well. The two students working together seemed to be able to accomplish what one of them alone may not have been able to do. This fits rather well Vygotsky's (1978) notion of the "zone of proximal development," which is the term applied to the difference between w lat a child can do alone and what he or she can do with assistance Students involved in joint productions could be thought of as operating within one another's zones of proximal development. Together they could provide both the component skills needed to solve the problem and the metacognitive information needed to coordinate, apply, and monitor the application of the skills. Working through the whole process together may have helped both students internalize the skills needed to solve such problems on their own in the future. As Vygotsky claimed (1962: 104), "What the child can do in cooperation today he can do alone tomorrow."

Limitations

When interpreting relationships involving student characteristic measures, it must be taken into consideration that the scales for learning preference are self-rating instruments. Social desirability was certain to have played a role in some students' responses. One student even wrote in the margin on the LPSS "I don't want to be an EGO MAN" next to the item that read "Other people's ideas are usually not as good as mine"; he selected the 1-point response, "completely false." Since these measures were not done anonymously, one must expect that some responses would be affected.

Other limitations of the study involve the equivalence of the experimental and comparison groups. Although the comparison group was taught by the same teacher using the same textbook and classroom structure initially used with the experimental group, the experimental group may have benefitted from the additional year of experience this teacher had teaching the Algebra II/Trigonometry course. This limitation is checked somewhat by the comparison that was made of the two groups' first seven chapter tests; no significant differences were found.

The comparison group also did not have benefit of any Hawthorne effect (the positive effect that often accompanies the introduction of anything new). This unaccounted-for instructional novelty likely had some effect, along with the experimental condition, on the achievement of the experimental group. This would be a more worrisome problem, though, if the hypothesis had been that achievement under scripted cooperative learning conditions was higher than that under conventional classroom instruction. But the hypothesis was that achievement would be at least as high or higher under the experimental condition. During instruction on the second chapter of the experimental phase, the Hawthorne effect might be expected to have worn off; students still did as well as the comparison group on the second chapter test. It could also be argued that the possibility of affecting students' long-term achievement, of which there was some evidence in this study, might well be worth the gamble of using scripted cooperative learning beyond the initial Hawthorne-effect period.

The generalization of the results of this study may be limited, since the experimental group did not contain students who scored in the lower stanines of the SAT. The range of Stanford Achievement Test mathematics scores in both the experimental and comparison classes was from stanine 5 to 9.

One other limitation involves the issue of the reliability of the some of the transcript coding. Some of the variables used had undergone reliability checks, namely the fidelity to the script scores and the off-task interaction percent score. However, the other coding schemes were carefully defined and executed without benefit of a second coder. These coding schemes demanded a level of intimacy with the data that was achieved only at great cost in terms of time, concentration, and expertise. Just to read through a transcript, one had to constantly follow the textbook page or worksheet on which the students had worked, oftentimes reading through erasures and interpreting local phraseology. On top of that, the reader had to thoroughly understand the mathematical concepts and skills the students were learning in order to follow their thinking and catch errors and misunderstandings. The mathematical topics at this high school level are not trivial: imaginary numbers, graphing quadratic equations, finding real and imaginary roots of polynomial equations of degree greater than 5 were just some of the topics of the lessons these transcripts covered. The coding schemes added another layer of complexity and could not be applied to the data until the coder had read through the transcript a number of times. A second coder capable of understanding the mathematics and able to devote the necessary time and energy to the coding task could not be found within the time and expense limitations of this study.

Conclusions and Implications

There seems to be strong evidence to support the conclusion that an effective program using dyadic studying techniques can be designed for use in a high school course in higher mathematics, like Algebra II/Trigonometry for 11th graders. Students can be expected to respond positively to the experience and to work cooperatively and productively together, following the scripted roles and activities with some customization over time.

This successful adaptation of "scripted cooperation" to a high school mathematics class should encourage other teachers and educators interested in designing instruction to consider the use of this method in their field of interest. The fact that older, "more sophisticated" students responded so positively and worked so productively under this program of scripted cooperative learning should discount many of the excuses high school teachers give for not using cooperative learning in their classrooms. This study does not argue for the total replacement of conventional instructional methods with cooperative learning structures, but rather for the inclusion of successful cooperative learning methods along with more conventional ones.

Another implication of this study for the implementation of similar cooperative learning structures with high school students is the importance of training. Time must be given to train students in the behaviors and interactions they are expected to use, and they must be given a strong rationale for doing what they are asked to do. It may also be worthwhile in classes where students do not know one another well to spend some time on team-building activities to set a positive tone of cooperation and support among all the members of the class before they are asked to work in small groups or pairs.

There are possibilities for further research using variants of the script developed for this study. This script was developed specifically to accommodate the features of the textbook being used by the class at the time. An examination of other popular high school mathematics books might result in a more generic script useful with a broader range of textbooks.

The interaction variables used in this study should be more formally examined for their relationship to achievement. From a theoretical point of view, joint productions in particular appear very promising for promoting achievement.

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